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PROGRESS REPORT

for Contract NASW-5052

PLASMA PARAMETERS FROM COORDINATED
SERTS AND YOHKHOH OBSERVATIONS

For the period February - November 1996

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ABSTRACT

The current study involves joint analysis of plasma parameter
measurements obtained from Yohkoh Soft X-ray Telescope (SXT)
broadband filter data, and from high-resolution EUV spectral
line data and spectroheliograms acquired during the 17 August
1993 flight of the Goddard Solar EUV Rocket Telescope and
Spectrograph (SERTS). These SXT and SERTS data provide
simultaneous, complementary information on the physical
conditions of the multithermal plasma in coronal structures.
This report is a summation of the data analysis and reporting
activities involving the SERTS/SXT data set which occurred
during the months of February to November 1996.

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ADMINISTRATIVE ISSUES

We are discussing with the NASA HQ Contracting Officer's
Technical Representative (COTR) and HQ Contracts officials the
possibility of a no-cost extension to the contract. The current
period of performance ends 1996 November 26. The basis for the
extension request is detailed in electronic mail to the COTR
on 1996 November 20-25. Briefly the reasons are: (a) the coincidence
of the contract period of performance with the intensive first year
of SoHO operations, in which the project Principal Investigator (PI)
spent much more time than anticipated; (b) the untimely death last
January of a key associated scientist on the project, Dr. Brunella
Monsignori-Fossi, who was helping with the multithermal analysis;
and (c) the direct application of the expected project results to
other NASA projects, including SOHO/Yohkoh/SERTS joint analyses and
inter-calibrations.

CONTRACT ACTIVITY FROM DEC 1995 THROUGH AUG 1996

Through February 1996 (the early commissioning phase of SOHO),
there was little direct progress under this contract beyond
discussions on the overall Yohkoh/SERTS plasma comparison project
with CoInvestigator Dr. Jeffrey Brosius of Hughes STX Corporation.
Dr. Brosius was funded independently for his part of the Yohkoh
Participating Scientist Investigation under contract NASW-5020,
which began six months earlier than NASW-5052, and ran from
1995 June 30 through 1996 June 29. Dr. Brosius was able to interact
strongly with Dr. Hirohisa Hara, a young Japanese colleague who
recently completed his thesis on Yohkoh SXT data analysis of
active regions. Dr. Hara, one of the leading experts on SXT active
region temperature analysis, came to visit us at Goddard and help
with the SXT plasma parameter analysis.

In May 1996, a paper entitled "The Structure and Properties of
Solar Active Regions and Quiet-Sun Areas Observed in Soft X-rays
with Yohkoh/SXT and in the Extreme Ultraviolet with SERTS," by
J.W. Brosius, J.M. Davila, R.J. Thomas, J.L.R. Saba, H. Hara,
and B.C. Monsignori-Fossi, was submitted to the Astrophysical
Journal; it was revised in July in accordance with the referee's
report and has been accepted for publication in the 1997 March
20 issue.

In July, the PI prepared paperwork for a subcontract from Lockheed
Martin to the University of Memphis, to bring into the project
Dr. Joan Schmelz, an expert in multithermal analysis of solar
active regions.

A) Multithermal Study of Joint SERTS and SXT Active Region data

Since August 1996, when Dr. Joan T. Schmelz was brought into the project, our efforts have concentrated on multithermal analysis of the joint SERTS and Yohkoh SXT observations of NOAA Active Region 7563 (at heliographic coordinates S01W15) on 1993 August 17. Accurate fluxes for both the SERTS spectral lines and the three Yohkoh broadband filters were obtained by Dr. Jeffery W. Brosius as a related part of this study (funded separately under contract NASW-5020). The SERTS data alone were used to produce a Differential Emission Measure (DEM) curve. The DEM analysis was done by Dr. Brunella Monsignori-Fossi before her untimely death on 1996 January 22. Dr. Monsignori-Fossi had one of the few working DEM codes designed and set up to work effectively on spectral data in the EUV wavelength range. The code was never made directly available to the other members of this team and, although Prof. Massimo Landini, Dr. Monsignori-Fossi's long-term collaborator, had hoped to step in and continue her work on this project, his many other commitments have not allowed him to spend as much time as was needed to do a full DEM analysis of the joint data set at this time.

Hence, we have approached the problem from the other direction. Rather than the full-scale inversion problem usually used to determine the DEM distribution, we have used the DEM curve produced by Dr. Monsignori-Fossi using the SERTS data alone (cf. Brosius et al. 1996) and folded it through the Yohkoh SXT filter responses to compare with the observed SXT data.

Dr. Monsignori-Fossi's DEM curve for AR 7563 is shown in Figure 8a from Brosius et al. (1996a), and redrawn here as the solid curve in Figure 1 here. The shape of the curve, especially the second hump at the high temperature end, peaking at about log T = 6.65, is unexpected since, at the time of the observations, AR 7563 was in a quiescent state with no flaring or unusual activity of any kind. Also, SERTS has no high-temperature spectral lines that could be used to accurately determine this end of the DEM distribution. It was, therefore, natural to use the Yohkoh SXT data to a) determine if the existing DEM curve is consistent with the SXT observations; b) if not, modify the DEM curve so that it reproduced the SXT fluxes observed through three of the different filters; and c) attempt to reconcile the differences, if any.

The first line of Table 1, below, shows the intensities from the SXT observations (in DN/sec -- please see Yohkoh analysis guide for the definition of Data Number) averaged to a 4.4116 square arcsec SERTS pixel for the three SXT filters used in this analysis. The second line gives the predictions resulting from the "forward-folding" technique using the original DEM curve (see solid curve in Figure 1). All resulting fluxes are too high be about a factor of five compared tothe SXT observed intensities. Since the SXT responses (see Figure 9 from Tsuneta et al. 1991) are relatively insensitive to temperatures below Log T = 6.3, the only way to effectively eliminate substantial flux from the DEM predictions (and not affect the cooler temperature results where the SERTS data provide strong constraints), is to eliminate emission measure at the high end of the solid DEM curve shown in Figure 1. This is done in small iterative steps until the

fluxes predicted from the forward-folding technique agree with those observed by SXT (within the approximately 10% measurement uncertainties). The DEM curve that produced the fluxes in the third line of the table below is shown as the dashed curve in Figure 1.

TABLE 1: Comparison of Observed Intensities with DEM predictions

SXT Filter	Al 0.1	AlMg	Al 12.
SXT Observed Intensities	1223.8	622.6	29.0
Original DEM Prediction	5748.4	3307.1	189.0
Revised DEM Prediction	1238.8	652.6	25.5

B) Joint Study of SERTS and SXT Quiet Sun Data

A similar procedure to that used for the active region was used to compare the quiet-Sun intensities observed by SXT with the DEM predictions, again by forward-folding the DEM curve through the SXT response. The quiet-Sun DEM curve calculated by Monsignori-Fossi is shown in Figure 9a of Brosius et al. (1996a) and redrawn as the solid line in Figure 2. The tail end of the solid DEM curve (log T > 6.25), which is essentially unconstrained by the SERTS quiet-Sun data, must decrease more quickly than the solid DEM curve to reproduce the SXT intensities. For the quiet-Sun case there apears to be no real conflict between the SERTS data and the SXT data. The SXT data provide a much stronger constraint to the DEM curve above log T = 6.25, while the SERTS data provide the strong constraint below, where the SXT response curves are falling off so fast that they are insensitive to the cooler plasma (log T < 2.5) unless there is almost no hotter plasma around in the same vicinity.

C) Uncertainties in the Analysis

One of the important caveats with this analysis is the set of element abundances assumed. There is still a great deal of controversy about the coronal composition, especially regarding the normalization of the trace elements with respect to hydrogen. Most measurements now imply different characteristic sets of coronal and photospheric abundances. In situ solar wind and solar energetic particle (SEP) data, as well as spectroscopic data, indicate that the first ionization potential (FIP) of the element is the dominant factor in determining how the coronal abundance of an element differs from its photospheric counterpart (Breneman & Stone 1985; Meyer 1985a,b). Relative to the photospheric composition baseline, low-FIP (<10 eV) elements are enhanced compared with high-FIP (>11 eV) elements, but it is still not clear whether, relative to hydrogen (which provides the bulk of the plasma), the low-FIPs are enhanced (cf Reames 1995, Feldman 1992) or the high-FIPs are depleted (cf Veck & Parkinson) or both (cf Fludra & Schmelz), or whether both are enhanced (cf Waljeski et al. 1994) or both depleted, but by different amounts. There are reported results which seem consistent with all or most of these possibilities. There is also evidence that the coronal composition might vary from one kind of structure to another (see, e.g., Widing & Feldman 1989), and possibly even within active regions (see, e.g., Strong et al. 1991).

Unfortunately, the DEM results of Brosius et al. (1996) assumed the elemental abundances tabulated by Feldman (1992) which assume

low-FIP element enhancement, while the SXT responses are calculated with the values tabulated by Meyer (1985) which assume high-FIP element depletion. There are fairly minor differences in the ratios of the heavy elements, but a factor of about 4 difference in the overall normalization of the heavies with respect to hydrogen.

Although these differences do not scale linearly (they affect the three SXT filters differently and also affect the details of the DEM shape), we have made a zeroeth-order correction to reconcile the results from the two different instruments, by scaling up the entire DEM curve by a factor of four to make it more consistent with the SXT filter responses. This correction will be made more accurately if the contract is extended.

The only lines effected by the changes in the DEM curve are the two Fe XVII lines at 347.8 A and 350.5 A that have the highest temperature peak responses of any of the SERTS spectral lines in the data set. Both are weak lines and, with no dominant hot lines to anchor the high end of the temperature distribution, it is possible that the fluxes of these lines could be equally well represented with the new DEM distribution. It is also possible that the two different iron ionization fraction calculations -- those by Arnaud & Raymond (1992) for the SERTS analysis and those by Arnaud & Rothenflug (1985) for the SXT filter responses -- could be a problem (although we expect they should be much less of a problem than use of the different sets of abundances). Although the Arnaud & Raymond (1992) do a more sophisticated calculation, and correct a known error, it is still not clear if this leads to a better result. This question may be resolved by SOHO-CDS measurements, in future independent SERTS analysis, or within this project, if time permits.

FUTURE WORK

In the course of our work to date, we have found some discrepancies in the initial independent SERTS and Yohkoh results. We need to resolve whether the source is the analysis methods, the abundances and/or ionization fractions used in the analyses, or the calibrations.

In the event of an extension, our first priority would be to put into the SXT analysis code the same iron ionization balance calculations and the same set of elemental abundances as used for the SERTS data analysis, and then redo our current SERTS/SXT comparison by forward folding the DEM curves already derived from the SERTS data through the SXT response curves and adjusting them for consistency with both sets of data.

If time permits, we would then reanalyze the SERTS data using the ionization balance calculations and abundances used in the SXT analysis, and do the full analysis on the joint data set, testing which combination of ionization fractions and abundances is more consistent with both data sets. This would provide information on the best assumptions to make for ion and abundance fractions in Yohkoh analyses where the information cannot be gotten independently, and an improved estimate of some systematic uncertainties. Further, it would give insight for SOHO/Yohkoh/SERTS cross-calibration.

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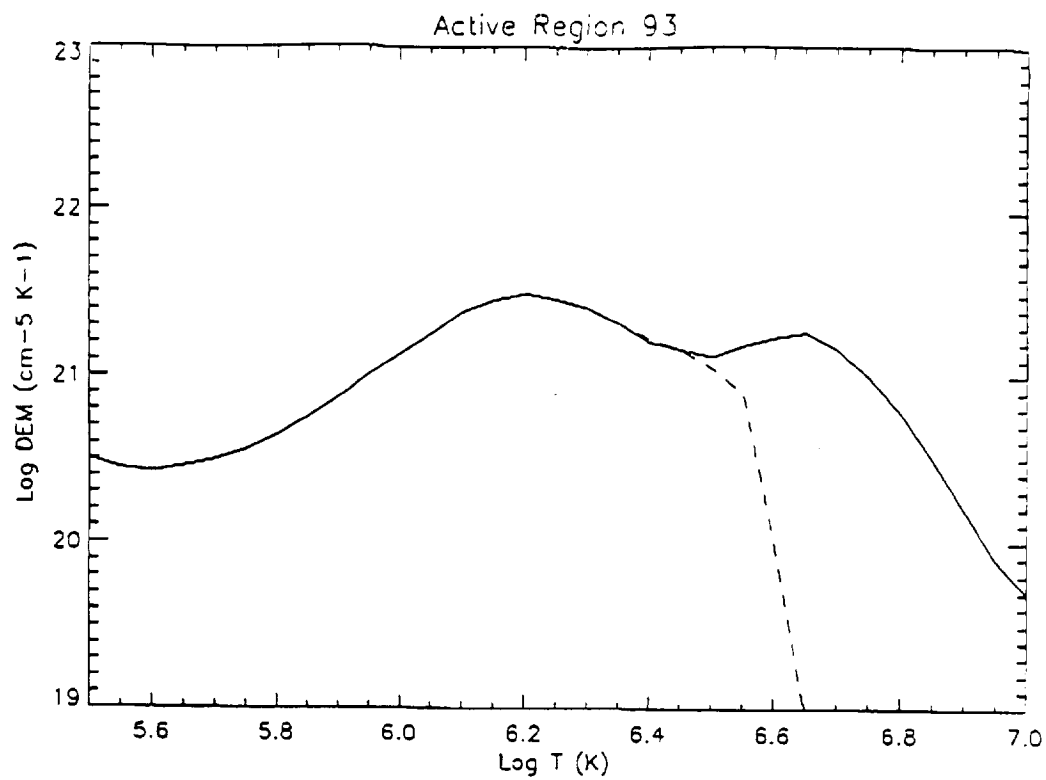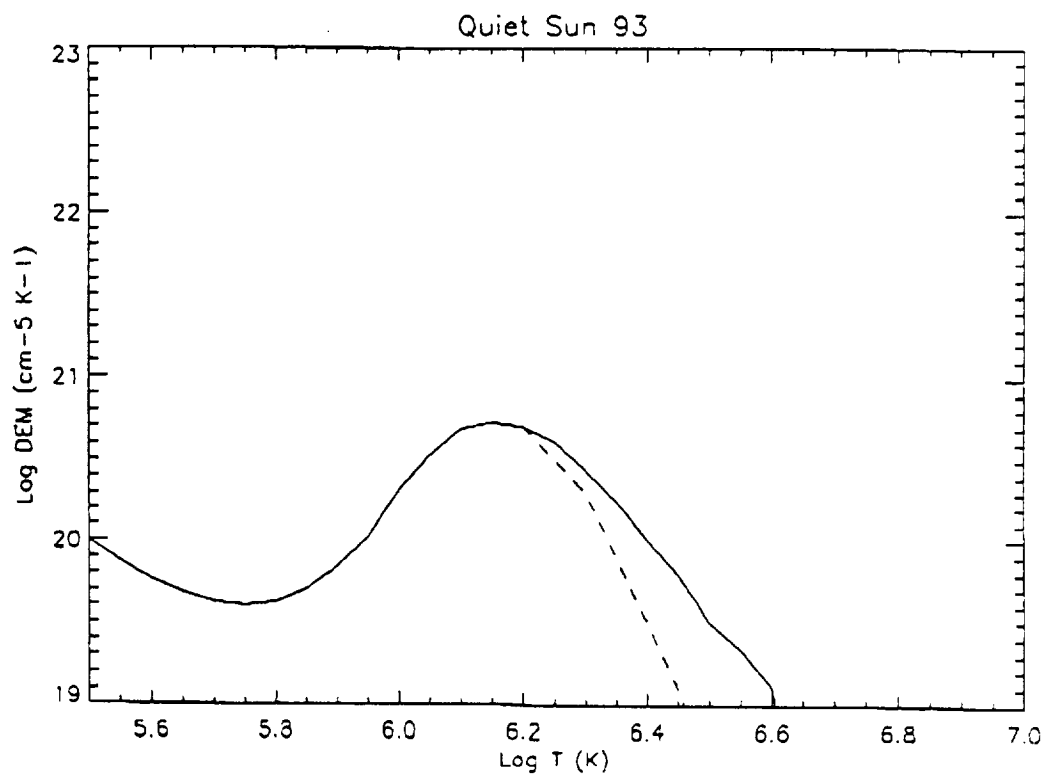Widing, K.G., & Feldman, U. 1989 ApJ, 344, 1046

Active Region 93

Figure 1

Quiet Sun 93

Figure 2

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16. ABSTRACT

The current study involves joint analysis of plasma parameter measurements obtained from Yohkoh Soft X-ray Telescope (SXT) broadband filter data, and from high-resolution EUV spectral line data and spectroheliograms acquired during the 17 August 1993 flight of the Goddard Solar EUV Rocket Telescope and Spectrograph (SERTS). These SXT and SERTS data provide simultaneous, complementary information on the physical conditions of the multithermal plasma in coronal structures. This report is a summation of the data analysis and reporting activities involving the SERTS/Yohkoh data set which occurred during the months of February to November 1996.

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